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USAF Aerospace Vehicle Test Course

Maj Gregg Leisman
Director, AVTC
USAF Test Pilot School
May 2005

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Next Course Offering

The US Air Force Test Pilot School at Edwards AFB will offer a 4-week Aerospace Vehicle Test Course in May of 2005 (Monday 2 May through Friday 27 May). The course is intended to educate select USAF engineers to plan, provision, execute, and report on testing of the next generation of USAF space vehicles. The course will consist of approximately 85 hours of academics supplemented with projects, simulation, fieldtrips, and flying.

Attendees must either have a degree in Aeronautical, Aerospace, or Astronautical Engineering, or have considerable experience in one of these fields. A general working knowledge of these areas is assumed. The course will be funded by the attendee's unit. All students must register by 14 March.

Point of contact regarding the Aerospace Vehicle Test Course is Maj Gregg Leisman,, DSN 527-8902, Comm (661) 277-8884, gregg.leisman@edwards.af.mil, or Lt Beverly Kocher, DSN 527-9867, beverly.kocher@edwards.af.mil

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USAF
Aerospace Vehicle Test Course

- Why an AVTC?
- Why at TPS?
- What is it?
  - Academics
  - Flying
  - Projects
- Funding?
- Future?

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Air Force Need

Secretary of Defense Donald Rumsfeld's 18 Oct 2001 Memo

"National Security Space Management and Organization"

The Secretaries of the Military Departments shall . . . assure space education . . . at all levels to ensure the cadre of space-qualified professionals . . . have a direct understanding of space activities and how space capabilities and applications are integrated into military operations. In addition, the number of advanced technical degree programs offered to space professionals shall be increased.

Air Force Need

- The Commission to Assess U.S. National Security Space Management and Organization
  - "The DoD is not yet on course to develop the space cadre the nation needs". These professionals "will have to master highly complex technology" and the report recommends "to create and sustain a cadre of Space Professionals"
  - Professionals for both the operation and acquisition of space systems. In fact, space acquisition become one of the focuses of the Commission.
- Test and Evaluation is a crucial step in acquisition that requires trained, professional officers.
  - Unlike the military aircraft acquisition community, no space test training is available.

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What is it?

Course Master Objective:

Educate select engineers to plan, execute, analyze, and report on testing of the USAF's generation of aerospace vehicles.

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Why TPS?

- TPS is a recognized leader in instruction of test principles and processes
- Aerodynamics and flight mechanics part of the curriculum
  - Flying part of the curriculum
- Access to facilities & test teams
  - NASA-Dryden, Scaled Composites at Mojave, Vandenberg Spaceport, RLV Ops and Test Complex (former X-33 Launch Site)
- SMC/TE (Kirtland) recommended in 1997 that TPS establish a course to support space test needs
- Air Force test expertise is at Edwards

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Recent Tests at Edwards AFB

X-38

X-40A

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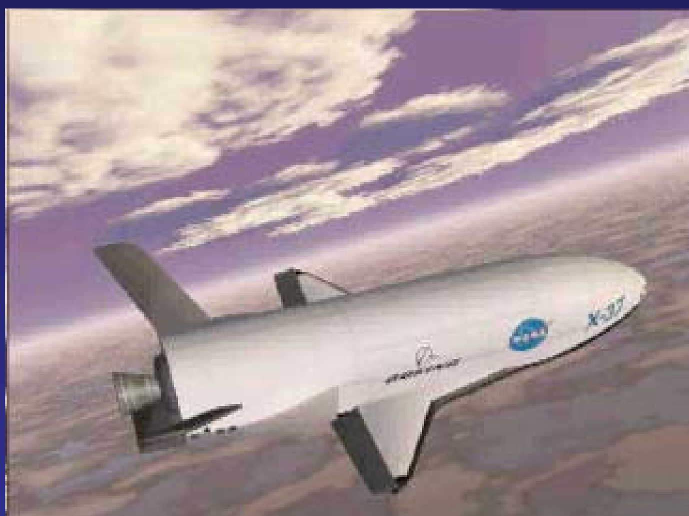
Currently in Test at Edwards AFB

X-37



X-43A

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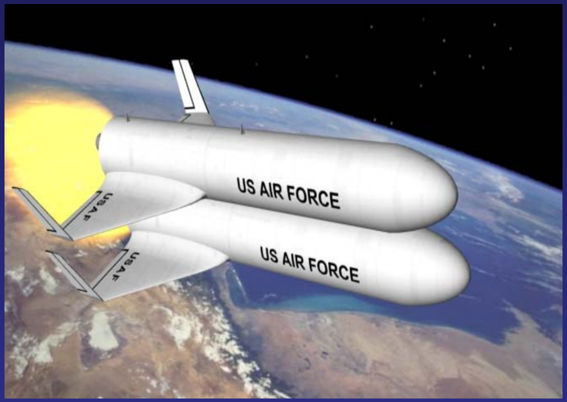
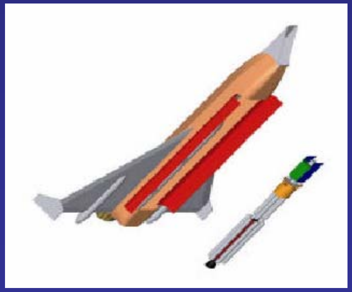
Future DoD Tests

Hypersonic
Weapons

Micro Sat Launch
Vehicle



Space Operations
Vehicle



Rascal

What is it?

- Immediate need is out there - SHORT COURSE (focus on aerospace vehicles, not satellites in space)
- 4 week course
- First: May 2000 – 6 students
- Second: Oct 2001 – 6 students
- Third: June 2003 – 12 students
- Fourth: June 2004 – 15 students

What is it?

- Attendees
  - B.S in Aeronautical Engineering
  - B.S. in Aerospace Engineering
  - B.S. in Astronautical Engineering

  OR

  - Extensive work in the space field
- Allows an accelerated course with focus on how issues apply to flight test

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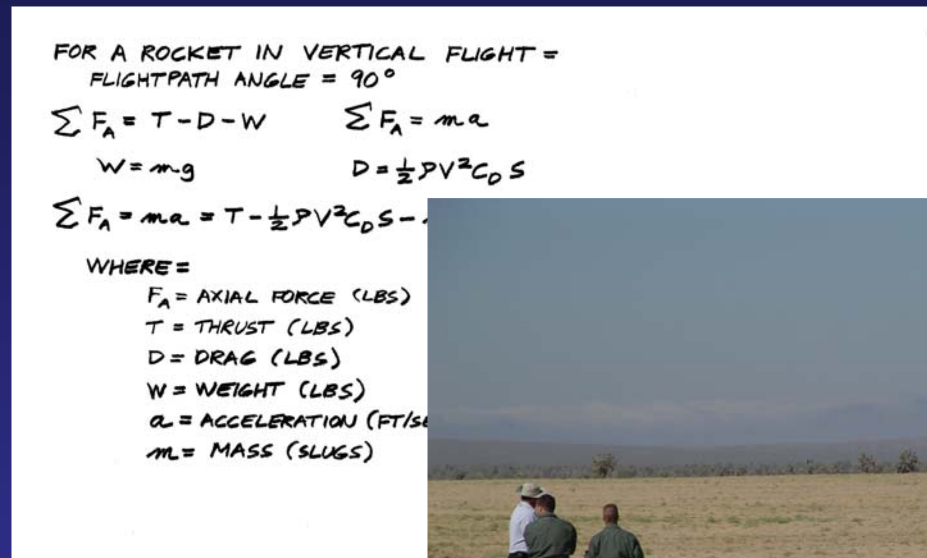
Curriculum Overview

- Academics
  - 80 hours
- Flying
  - 3 + 1 Events
  - 2 Simulations
- Projects
  - 3 Projects
- Field Trips


FOR A ROCKET IN VERTICAL FLIGHT =
FLIGHTPATH ANGLE = 90°

$\sum F_A = T - D - W$ $\qquad$ $\sum F_A = ma$

$W = mg$ $\qquad$ $D = \frac{1}{2}\rho V^2 C_D S$

$\sum F_A = ma = T - \frac{1}{2}\rho V^2 C_D S -$

WHERE =
F_A = AXIAL FORCE (LBS)
T = THRUST (LBS)
D = DRAG (LBS)
W = WEIGHT (LBS)
a = ACCELERATION (FT/S
m = MASS (SLUGS)

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Academics

Welcome, Intro, Overview
Historical Perspective
Future of Aerospace Planes
Subsonic Aero
Supersonic Aero
Transonic Aero
Flight Dynamics
Long Stat
The Atmosphere
Air Data Systems
Aero Flight Controls
Lat-Dir
Aircraft EOM
Long Dynamics and Test
Lat-Dir Dynamics and Test

Telemetry and TSPI
Control Room Ops
Propulsion
Modeling and Simulation
Hypersonic Aero
Space Vehicle Attitude Controls
Ascent Equations
Spacecraft Attitude Dynamics
Flight Test Buildup
Orbital Mechanics
Orbital Perturbations
Orbital Rendezvous
Aeroelasticity
Spacecraft Reentry
Thermal Protection Systems

Environmental Planning
Mission Analysis & Tradeoffs
Manned Spaceflight Issues
Space Shuttle Launch
Space Shuttle Return
The Space Environment
Spacecraft Communications
Spacecraft Tracking
Sensors
Guidance, Nav, & Control
Flight and Range Safety
Safety Case Studies
Space Test Flight Profiles
The Test Process
Space Lessons to be Learned

Historical Speakers

Flying

- Intro to Unpowered Flight (L-23 and ASK-21)
- Intro to High Performance Flight (T-38)
- High Performance Fighter Demo, Sensor Operations, & Departures (F-16)

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Why Fly?

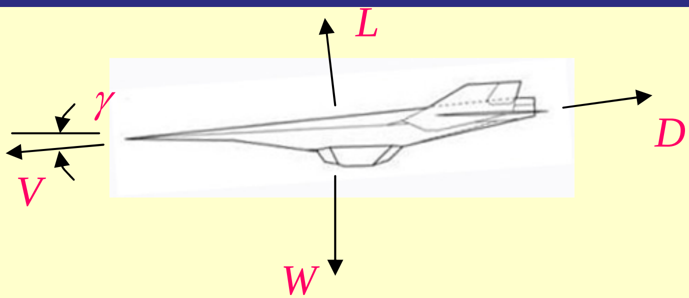
- Most attendees never exposed to USAF aerospace equipment
- Limited experience with flight controls or flight environment
- Reinforce academics and flight test techniques
- Build confidence in aerospace operations
- Motivation!

Gliders

Learning Objectives

- Towed operations and space applications
- Aborted tow or aborted takeoff decision points and parallels with spacecraft launch operations
- Experiment with the effects of traditional controls
- Experience speed stability, maneuvering flight, steady heading sideslips, as well as the dynamical modes of the glider to include phugoid, short period, Dutch roll, roll mode, and spiral mode
- Observe the aeroelastic response of aero. structures
- Practice energy management techniques

Theory and Flight Test Techniques



$D = W \sin\gamma = W\,(V_S/V) = (W/V)\,(\Delta H/\Delta t)$

$\gamma = \sin^{-1}(D/W)$

$L = W \cos\gamma$

$q = \frac{1}{2}\rho V^2$, where $\rho = f(H \text{ or } p, T)$

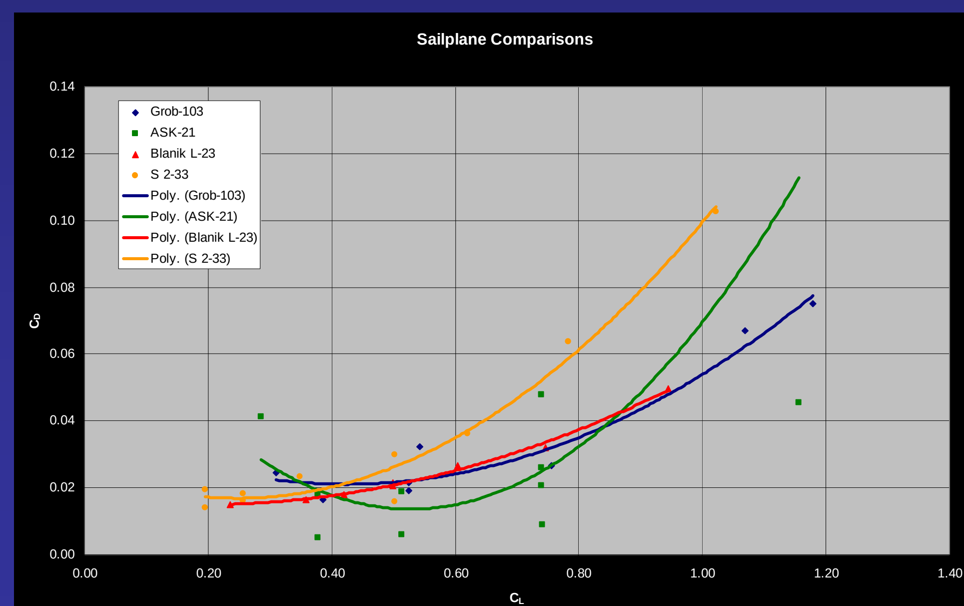
$C_D = D/(qS)$

$C_L = L/(qS)$

$$\zeta \approx \frac{1}{\sqrt{2}}\frac{C_D}{C_L} = \frac{1}{\sqrt{2}(L/D)}$$

$$\omega_n \approx \frac{\sqrt{2}g}{V_t}$$

Results

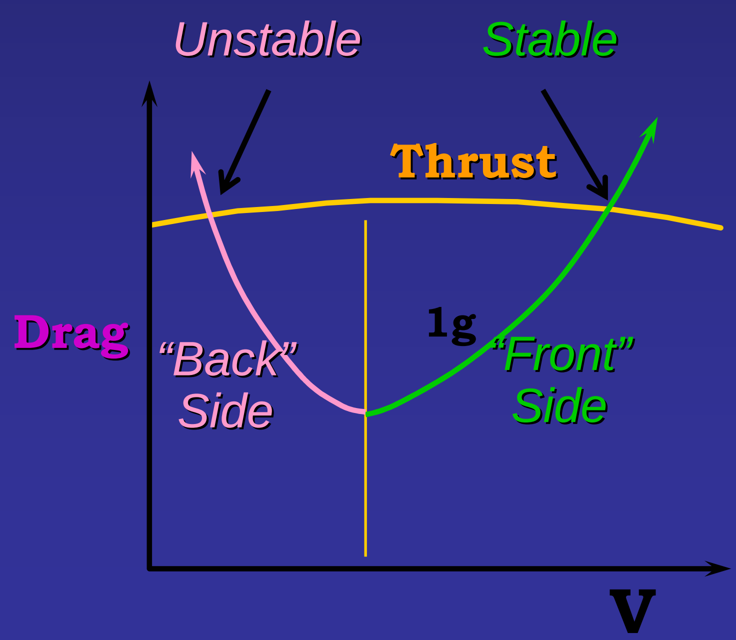


T-38

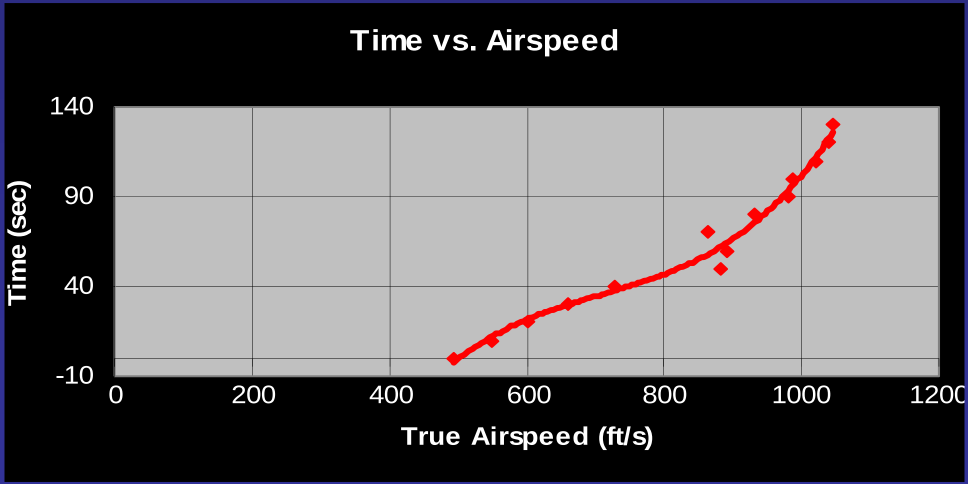
Learning Objectives

- General operation of USAF aerospace vehicles
- Cockpit instrumentation and limitations of the man-machine interface
- Radio communications
- Experience flight dynamics to include aircraft longitudinal acceleration and deceleration, g-forces, and coordinated versus uncoordinated flight
- Stall characteristics of a typical low aspect ratio aircraft
- Lifting body and Shuttle approach profiles

Theory and Flight Test Techniques



Results

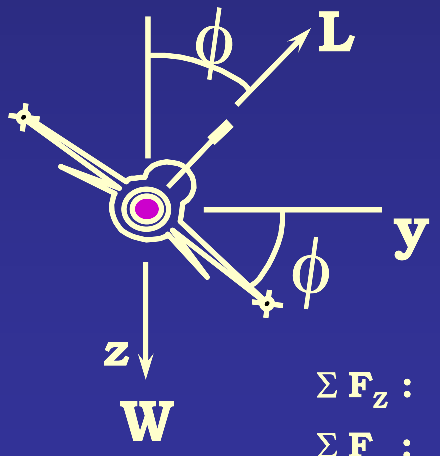


F-16

Learning Objectives

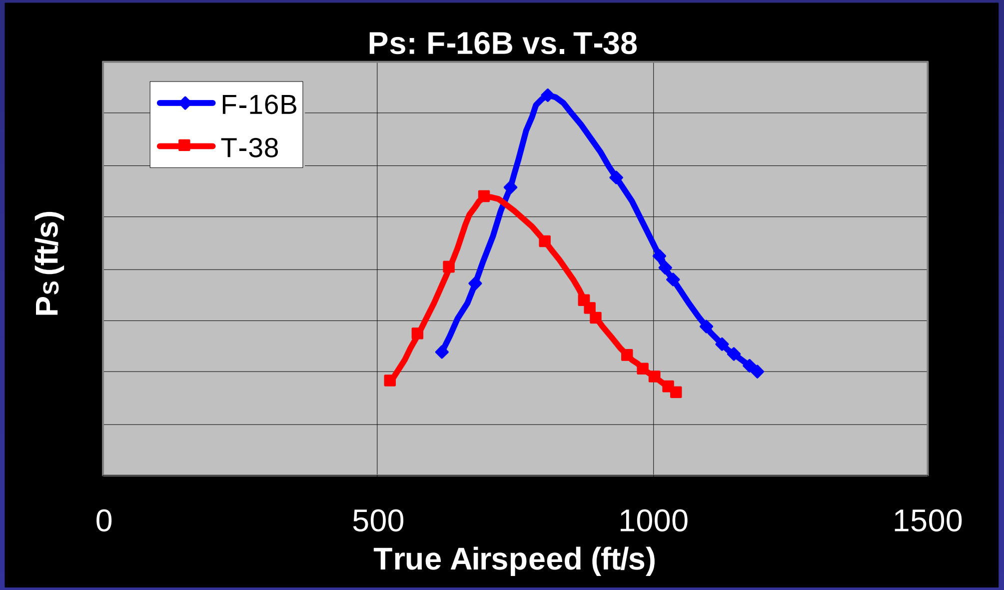
- Maximum performance takeoff and departure and associated physiological effects
- Cockpit management in a restricted environment
- Flight maneuvers using a sidestick controller
- HUD symbology
- Inflight sensor (radar) for air-to-air operations
- Mapping radar for navigation or position updates
- Departure and deep stall characteristics of an aircraft with relaxed longitudinal stability
- Energy management associated with a SFO appr.

Theory and Flight Test Techniques



$$\Sigma F_z : \quad L\cos\phi = W$$
$$\Sigma F_y : \quad L\sin\phi = m a_y$$

Results



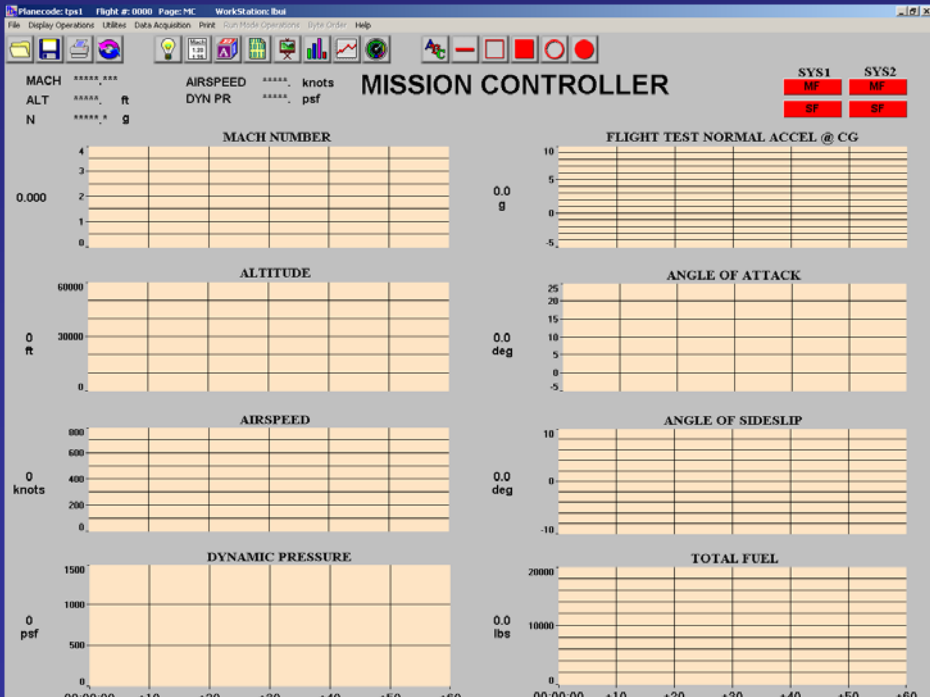
Test Projects

- F-15 Microsat Launch Sim and Control Room
- X-plane Flight Test Design, Flight, and Data Reduction
  - Single test profile development
  - Fly in the NASA X-33 simulator
  - Oral report on Test Results
- Rocket Project
  - Design and data reduction exercise

MSLV Sim

Learning Objectives

- Test execution discipline
- Proper communication within test team
- Control room conduct and procedures
- Overview of flight test procedures
- High performance aircraft cockpit familiarization
- Introduction to Microsat Launch Vehicle program

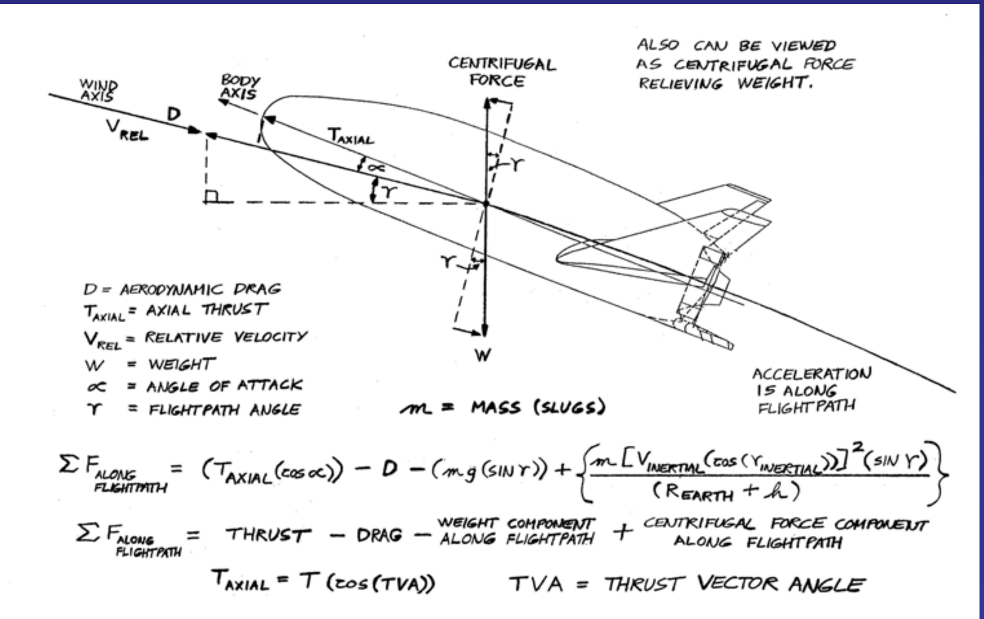


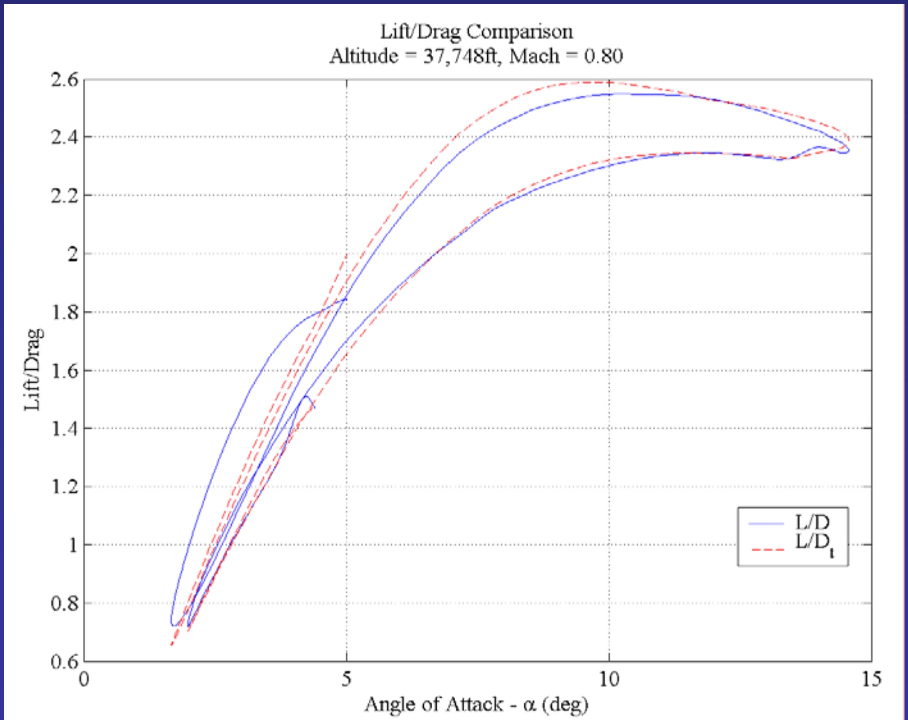
RLV Project

Learning Objectives

- Application of simulations to flight testing
- Gather Data to Investigate Capabilities and Robustness of the X-33
- Ascent Profile Analysis
- Vehicle Aerodynamic Performance Study
- Terminal Area Energy Management

Theory and Flight Test Techniques





Rocket Project

Learning Objectives

- Practice flight test discipline: plan, execute, report
- Flight Test 3 AVTC instruments rockets
- Determine if the rocket and motor meet performance requirements
- Compare actual performance based on flight test data with manufacturer's performance predictions

Theory and Flight Test Techniques

FOR A ROCKET IN VERTICAL FLIGHT =
FLIGHTPATH ANGLE = 90°

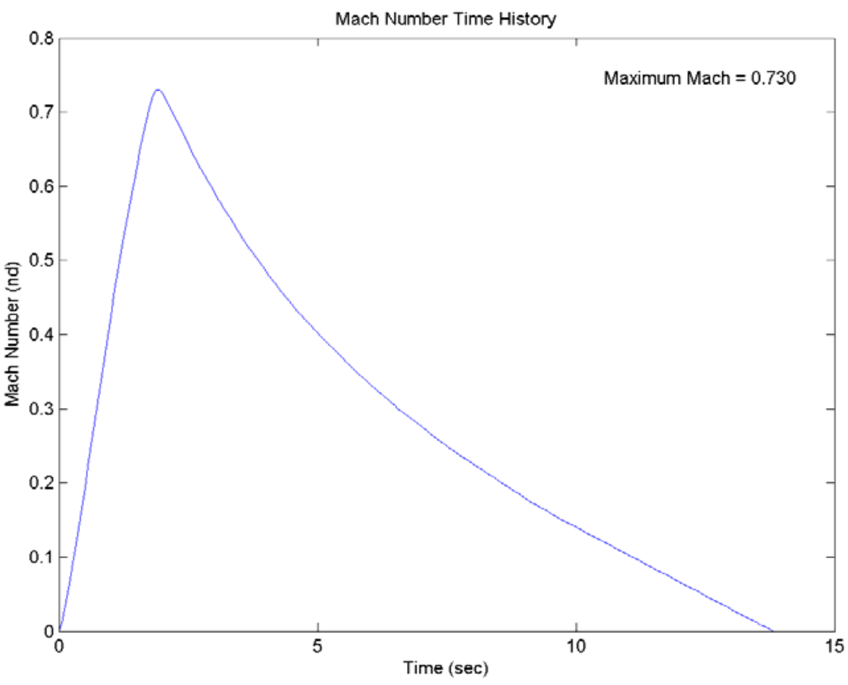
$\sum F_A = T - D - W$ $\sum F_A = ma$

$W = mg$ $D = \frac{1}{2}\rho V^2 C_D S$

$$\sum F_A = ma = T - \frac{1}{2}\rho V^2 C_D S - mg$$

WHERE =

- F_A = AXIAL FORCE (LBS)
- T = THRUST (LBS)
- D = DRAG (LBS)
- W = WEIGHT (LBS)
- a = ACCELERATION (FT/SEC²)
- m = MASS (SLUGS)
- g = ACCELERATION OF GRAVITY 32.174 FT/SEC²
- ρ = ATMOSPHERIC DENSITY (SLUGS/FT³)
- V = VELOCITY (FT/SEC)
- C_D = DRAG COEFFICIENT (DIMENSIONLESS)
- $S = \pi R^2$ REFERENCE AREA (MAX CROSS-SECTIONAL AREA) (FT²)



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Field Trips

- Johnson Space Center (2 full days)
  - Fly space shuttle simulators
  - Interact with the astronauts
  - Tour training facilities
  - Zero-G training
- Reusable Launch Vehicle Operations and Test Complex (half day)
  - See the facilities associated with space vehicles
- Rocket Lab (half day)
  - See future propulsion systems research and ground test facilities
- Vandenberg Spaceport (full day)
  - Understand current spacelift infrastructure
  - Tour operational spacelift complex
- Scaled Composites
  - Insight into current commercial space ventures

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Scaled Composites Tour

Funding

- $24.5 K per student
  - Pays for all flying, text books, uniforms, and materials
  - Does not include TDY costs (approx. $5-6 K)

- Minimum of 6 students; maximum of 15 students
- Funding provided by student’s organization

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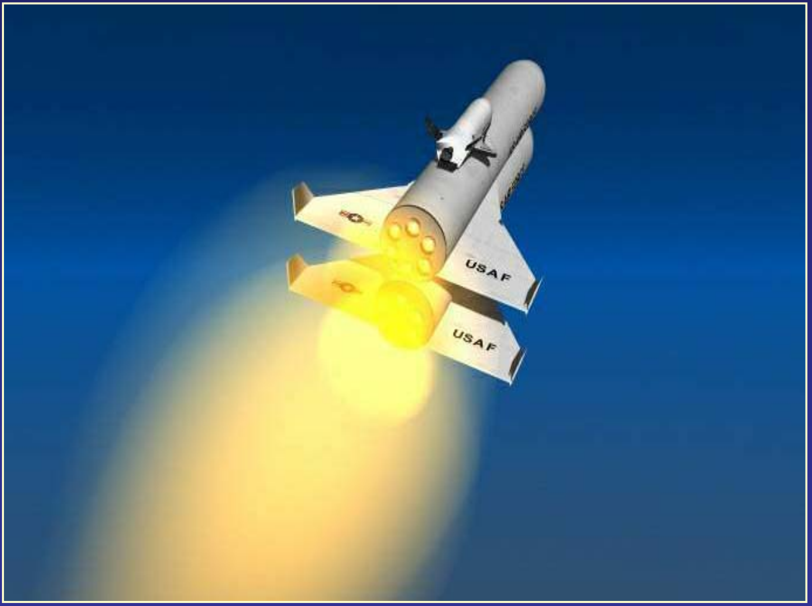
Summary

Since early in the 20th century when the Wright Brothers first took to the skies, the flight path for aerospace power has been onward and upward. The pioneers who established the United States Air Force were committed to achieving aerospace power's enormous potential ….

We are an integrated aerospace force. Our domain stretches from the earth's surface to the outer reaches of space in a seamless operational medium. We operate aircraft and spacecraft optimized for their environments, but the art of commanding aerospace power lies in integrating systems …

U.S. Air Force, Vision 2020



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Questions